CSI4124/SYS5110
Final Exam 2009 – Annex

Painting Parts Project

1 SUI Key Features

1.1 Introduction

In a heavy machinery manufacturing plant, after large and heavy machine parts are constructed, they are painted at a "painting station". Only one worker works at the painting station. The painting is completed in two operations; Painting 1 and Painting 2.

The machine parts are too heavy to be moved and repositioned by the worker at the painting station. An overhead industrial manipulator is used to fetch the machine part from storage and place it at the station for Painting 1, reposition the part between Painting 1 and Painting 2, and move the painted part back to storage after Painting 2.

As described in the SUI Details section below, the duration of manipulator operations are considerably smaller than those for the painting operations. Thus a single manipulator can service multiple painting stations. Management is interested in how many painting stations can be serviced by a single manipulator.

1.2 Goal of project:

A steady-state study is to be used to study the operation of painting machine parts to determine how many painting stations should be serviced by a single manipulator. The number of painting stations should be selected to obtain high station and manipulator utilization. A small number of stations per manipulator ensure that painting station utilizations are high, but this leads to underutilisation of the manipulator. Having many stations per manipulator keeps the manipulator busy, but may increase painting station idle times waiting for a manipulator. It is of interest to find the right number of stations per manipulator to make good use of both manipulators and stations.

1.2.1 Output:

Using a steady-state study, the project goal is to investigate how the number of stations serviced by a single manipulator is changed from three, to four, to five to six affects the following output:

- The utilization of the manipulator (percentage of time the manipulator is busy).
- The utilization of the stations (percentage of time the manipulator is busy). The utilization of stations is averaged over all stations.

1.3 SUI Details

The process of painting a part at a painting station consists of the following steps:

1. Painting 1: Operator completes Painting 1 operation of the part.
2. Reposition Part: The manipulator is used to reposition the part at the painting station.
3. Painting 2: Operator completes Painting 2 operation of the part.
4. Store and Fetch: The manipulator is used to move the finished part to storage, and fetch another unpainted part from storage to bring it to the painting station.
5. Return to (1).

The above steps assume that a part has been initially loaded onto each painting station. The painting station becomes idle after each painting operation (Painting 1 and Painting 2) while waiting for the manipulator to become available and complete the Reposition Part and Store and Fetch operations. The duration specifications for each of the steps are given in the following table.

Operation	Duration
Painting 1	Empirical continuous distribution f1 (in minutes) with the following cumulative distribution: **f1** **F(f1)** 60 0.0 70 0.12 80 0.48 90 0.83 100 1.0
Reposition Part	Uniformly distributed between 10 and 20 minutes.
Painting 2	Empirical continuous distribution f2 (in minutes) with the following cumulative distribution: **f2** **F(f2)** 80 0.0 90 0.24 100 0.73 110 1.0
Store and Fetch	Uniformly distribute between 25 and 35 minutes.

Notes:

1) Conflicts can arise over the use of the manipulator. At any given time, one or more stations may require use of the manipulator for the Reposition operation, while one or more stations may require the manipulator for a Store and Fetch operation.
2) Because the Reposition operation requires less time, it has the higher priority and thus all Reposition operations are completed before any Store and Fetch operations are undertaken.
3) Pre-emption of operations is **not** possible.
4) Stations are serviced by the manipulator on a first-come first-serve basis; that is, for stations waiting for a Store and Fetch operation, the one which has been idle the longest is serviced first. Priority (see point 2) is always respected, i.e. the idle time is not taken into account when considering priorities.

ABCmod Standard Modules

- InsertQue(QueueName, Item): Inserts Item into a queue entity called QueueName according to the declared queuing protocol associated with QueueName.
- InsertQueHead(QueueName, Item): Inserts Item at the head of a queue entity called QueueName..
- Ident ← RemoveQue(QueueName): Removes the item which is at the head of the queue entity called QueueName. Ident is the identifier for the returned item.
- InsertGrp(GroupName, Item): Inserts Item into the group entity called GroupName.
- RemoveGrp(GroupName, Ident): Removes an item from the group called GroupName. Ident is the identifier for the item to be removed from the group.
- Ident ← RemoveGrpAny(GroupName): Removes an arbitrary item from the group called GroupName. Ident is the identifier for the item removed from the group.
- Put(*PHY[y],* Val): Places the value Val into the sample set called *PHY[y]*
- Ident ← Derive(EntityStructureName): Derives an entity with identifier Ident from the entity structure called EntityStructureName.
- Leave(Ident): It frequently occurs that a specific entity's existence within the model comes to an end. This module explicitly indicates such an occurrence and its argument is the identifier of the entity in question. The module is typically invoked within the SCS of the terminating event of an activity instance.
- Terminate: An instance of a (Triggered) Extended Activity construct that undergoes an intervention must necessarily terminate. This is made explicit by ending the SCS of each intervention sub-segment with a reference to the Terminate module.

Interval Estimation

$$\bar{y}(n) = \frac{1}{n}\sum_{k=1}^{n} y_k$$

$$s^2(n) = \frac{\sum_{k=1}^{n} (y_k - \bar{y}(n))^2}{n-1}$$

$$\zeta = \frac{t_{n-1,\alpha} s(n)}{\sqrt{n}}$$

Student t-Distribution

	Confidence C									
Degres of Freedom	0.9	0.91	0.92	0.93	0.94	0.95	0.96	0.97	0.98	0.99
9	1.83	1.90	1.97	2.06	2.15	2.26	2.40	2.57	2.82	3.25
19	1.73	1.79	1.85	1.92	2.00	2.09	2.20	2.35	2.54	2.86
29	1.70	1.75	1.81	1.88	1.96	2.05	2.15	2.28	2.46	2.76
39	1.68	1.74	1.80	1.86	1.94	2.02	2.12	2.25	2.43	2.71
49	1.68	1.73	1.79	1.85	1.93	2.01	2.11	2.24	2.40	2.68
59	1.67	1.72	1.78	1.85	1.92	2.00	2.10	2.22	2.39	2.66
69	1.67	1.72	1.78	1.84	1.91	1.99	2.09	2.22	2.38	2.65
79	1.66	1.72	1.77	1.84	1.91	1.99	2.09	2.21	2.37	2.64
89	1.66	1.71	1.77	1.83	1.91	1.99	2.08	2.21	2.37	2.63
99	1.66	1.71	1.77	1.83	1.90	1.98	2.08	2.20	2.36	2.63